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PETROGRAPHICAL CHARACTERISTICS OF VARISCAN GRANITOIDS OF BATTONYA UNIT BOREHOLES (SE HUNGARY)

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ABSTRACT

The Tisia Composite Terrane Alpine megatectonic unit forms the pre-Neogene crystalline basement of South, Southeast Hungary. As an independent unit the Tisia Composite Terrane existed from the Late Cretaceous, when its rotation began, till the Early Miocene. Concerning the territory of Hungary it involves three large Variscan Terranes (Slavonia-Dravia Terrane, Kunságia Terrane and Békésia Terrane), all of which are covered by an Alpine overstep sequence. The Békésia Terrane can be divided into four units: Kelebia Unit, Csongrád Unit, Battonya Unit and the Sarkadkeresztúr Unit. The crystalline mass of the Tisia Composite Terrane is characterised by granitoid ranges and anticline wings of middle and high grade metamorphites. This paper presents the results of a petrological analysis on granitoid rocks originating from boreholes that were deepened in the axis zone of the crystalline dome (Battonya High) of the Battonya Unit. The available granitoid rocks, on the basis of their composition can be considered of similar character. The main rock forming minerals of the studied samples are: quartz ± orthoclase + microcline + plagioclase feldspar (albite-oligoclase) ± biotite + muscovite. Accessory components are apatite, zircone, monacite and less frequently titanite. Considering the modal composition of the rocks, they are syenogranites, monzogranites and granodiorites. Based on their chemical composition, the rocks are syenogranites, monzogranites and granodiorites they are subalkaline, calcic with a peraluminous character. Tectonically they are orogenous, syn-collisional or continental collisional granitoids. Most of the characteristics featuring the Battonya Unit samples indicate that they are S-type granitoids.

Key words: S-type syn-collisional CC granitoids, geochemistry, crystalline basement, Battonya Unit, Tisia Composite Terrane, Pannonian Basin, Hungary

INTRODUCTION

The present geology and tectonical setting of the Carpathian Basin (Pannonian Basin) (Fig. 1A) and that of Hungary is a result of a compound, multi-step evolution of geological structures. The complexity is reasoned first of all by the megatectonic location of the territory, since it is the actual collision zone of the European and African continental plates with oceanisation and the series of collisions, which lead here to the splintered fragmentation of the lithosphere. During the Alpine Orogenesis the nappe formation and folding processes were accompanied by the drifting and detachment of the fragments. At the end of the Miocene the attenuation of the crust (anticlines of the mantle) launched the development of large basins, that determine the present structural setting of the area.

The greatest proportion of the Pre-Neogene basement of the Pannonian Basin is built up by two Alpine megatectonic units, namely, the Pelsoian Composite Terrane in the North (comprising the Southern part of the ALCAPA Composite Terrane), and the Tisia Composite Terrane in the South (Kovács et al., 2000).

The crystalline mass of the Tisia Composite Terrane is characterised by granitoid ranges and anticline wings of middle and high grade metamorphites. This paper presents the results of a petrological analyses on the granitoid rocks located in the characteristic uplift (Mezőhegyes-Battonya) of the basement of the Békésia Terrane (Battonya Unit) – Tisia Composite Terrane (Fig. 1B).

GEOLOGICAL SETTING

The Tisia Composite Terrane (Fig. 1A) comprises the crystalline basement of South Hungary, East Croatia, North Yugoslavia and that of the Western part of Transylvania (Romania). It is bordered by the Mid Hungarian lineament, the Száva-Moslavima-Zombor-Bečej-Lipova line (the Northern border of the Srem - Mureş ophiolite belt) and the Someş lineament in the Northwest, South and Northeast, respectively. As a consequence of the fact that at the present the basement is covered by Miocene-Pliocene sediments at a depth of 2500-6500 m, its structure and petrology can only be investigated with geophysical methods and borehole samples. The seismic research of the past decades has shown that during the Neogene the Pannonian Basin has gone under a complex tectonic evolution, that has principally modified the original Variscan structures of the area (Albu et al., 1992; Tari et al., 1999; Csontos, Nagymarosi, 1999). As an independent unit the Tisia Composite Terrane existed from the Late Cretaceous, when its rotation began, till the Early Miocene. Concerning the territory of Hungary it involves three large Variscan Terranes (Slavonia-Dravia Terrane, Kunságia Terrane and Békésia Terrane), all of which are covered by an Alpine overstep sequence. From the beginning of the Late Triassic up to the Early Cretaceous a characteristic separation is recorded by sedimentary successions. Although, these units thrusted, and formed nappe zones during the Middle-Late Cretaceous, sometimes lateral transitions can be detected as well (Kovács et al., 2000).

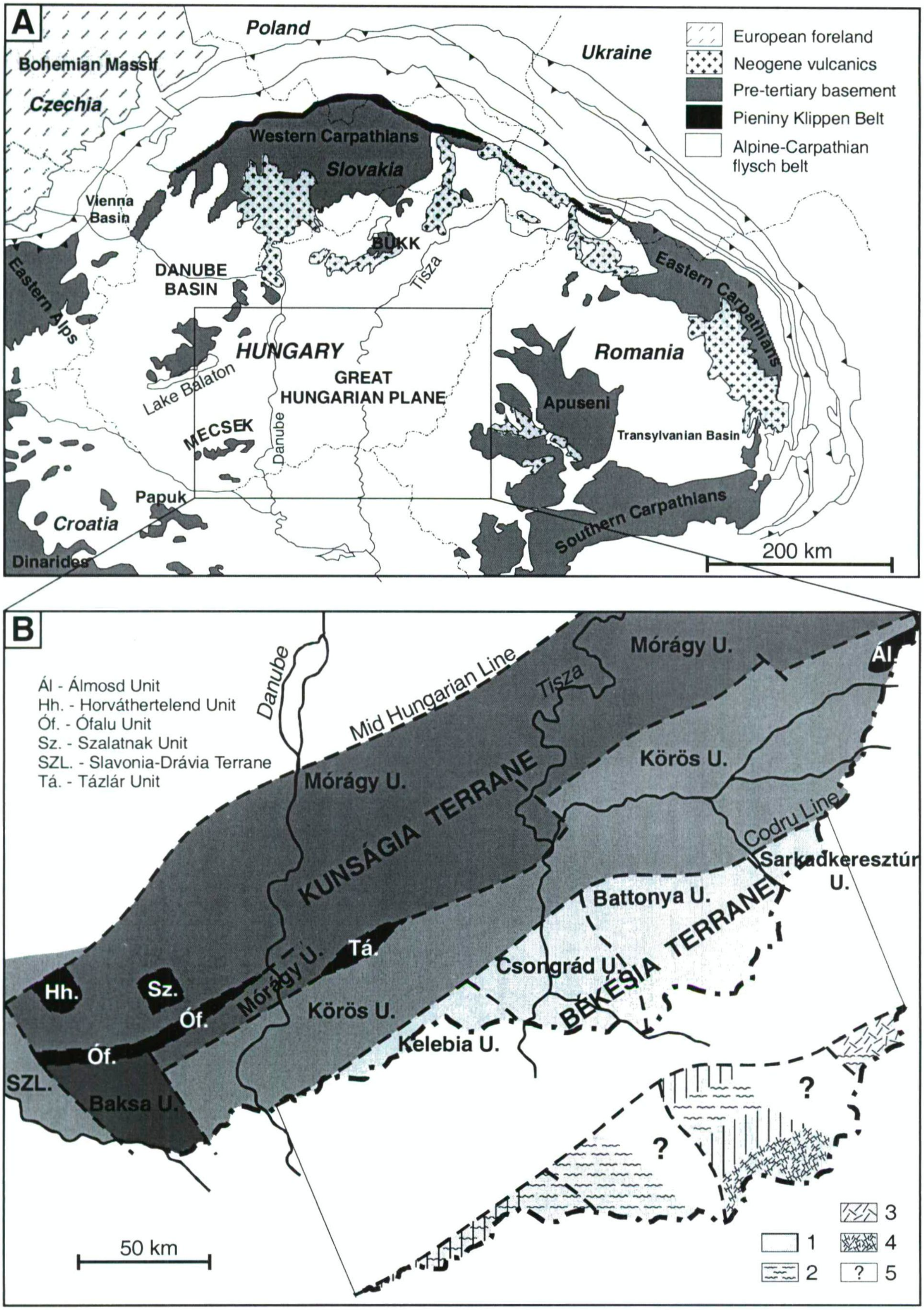
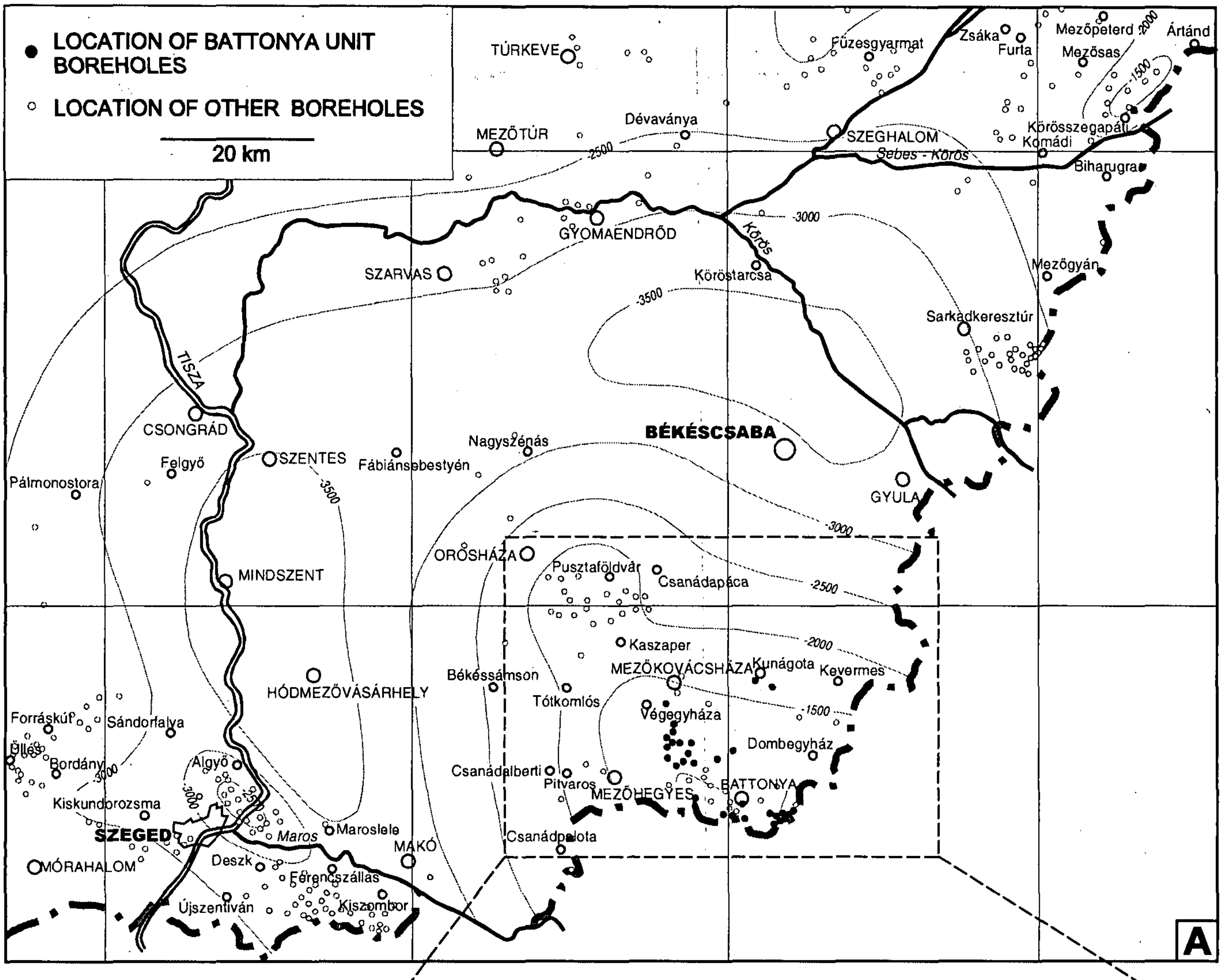


Fig. 1. (**A**) The simplified geological map of the Alpine-Carpathian-Pannonian region. (**B**) Pre-Tertiary regional geology of the Tisia Composite Terrane (SE part of the Pannonian Basin); Békésia Terrane highlighted (modified after Kovács et al., 2000). Legend: 1. Alpine overstep sequence connected to the northern shelf of the Axios/Vardar and related Neotethyan oceanic basins; 2. Variscan medium-grade metamorphosed complex; 3. Migmatic complex; 4. Granitoids; 5. Unknown.



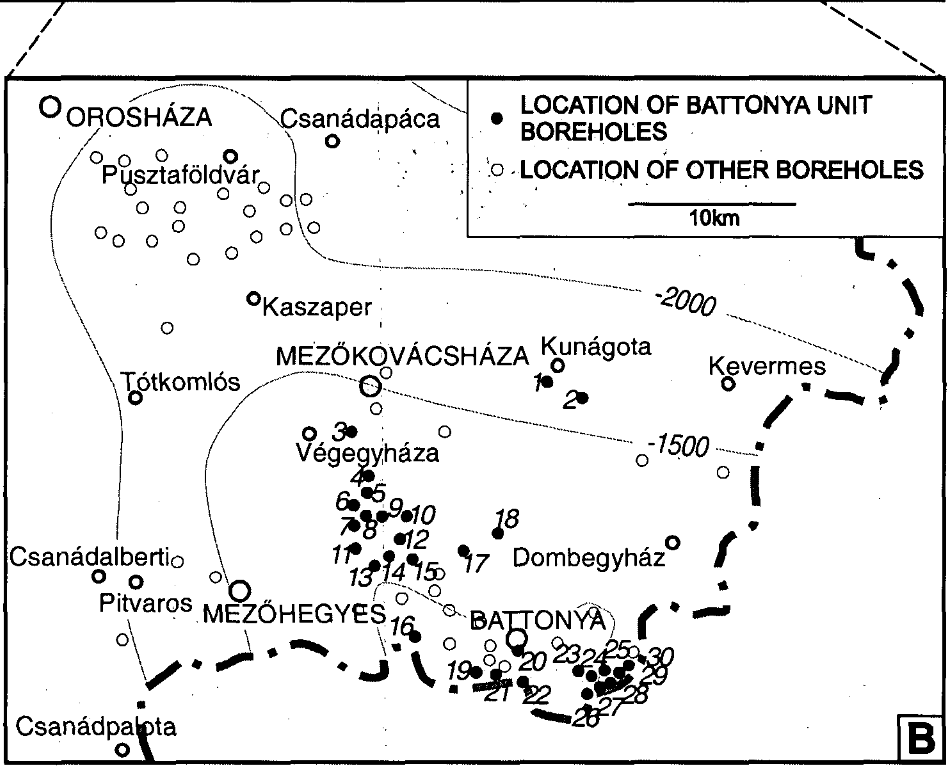


Fig. 2. (**A**) The map of SE Hungary, complemented with the topography of the Pre-Neogene basement and the location of the studied boreholes. (**B**) Precise location of the studied Battonya Unit boreholes. The numbers stand for the following boreholes:
1. Kunágota-2, 2. Kunágota-1, 3. Végegyháza K-1, 4. Végegyháza-2, 5. Mezőhegyes-14, 6. Mezőhegyes-7, 7. Mezőhegyes-5, 8. Mezőhegyes-6, 9. Mezőhegyes-19, 10. Mezőhegyes-11, 11. Mezőhegyes-2, 12. Mezőhegyes-8, 13. Mezőhegyes-1, 14. Mezőhegyes-9, 15. Mezőhegyes-12, 16. Mezőhegyes-20, 17. Dombegyház DNy-2, 18. Dombegyház DNy-1, 19. Battonya-3, 20. Battonya-10, 21. Battonya-64, 22. Battonya-76, 23. Battonya-6, 24. Battonya K-6, 25. Battonya K-9, 26. Battonya K-18, 27. Battonya K-16, 28. Battonya K-11, 29. Battonya K-13, 30. Battonya K-14.

The areas of interest are situated on the Békésia Terrane, which is the part of the Békés-Codru Alpine Zone. The name Békésia Terrane is only applied to the Hungarian part of the basement, since detailed comparative investigations of the Codru Zone in Romania are still missing. The Békésia Terrane can be divided into four units: Kelebia Unit, Csongrád Unit (earlier Tisza Unit (Szederkényi, 1984, 1996)), Battonya Unit (earlier Battonya Complex (Szederkényi, 1984, 1996)) and the Sarkadkeresztúr Unit (Fig. 1B).

The borholes exposing the studied granitoid samples are located in the Battonya Unit (Fig. 2A). The Battonya Unit effectively is a 15-25 km long and 10-15 km wide body with a round-shape layout, forming a flat anticline that is covered by Miocene and Pannonian strata. Its borders are: the front of the South Hungarian Nappe Belt in the north, the Makói Trench in the west, the Békési Basin in the east, and it stretches till the northern front line of the Biharia Nappe in Romania. The average depth of the Hungarian section below the surface is 1000-1500 m (Fig. 2A-B), though, in the surroundings of Pitvaros and Kunágota and in Kevermes it can be detected in a 2000 m depth.

According to Buda (1996), the granitoid rocks have a compound crustal-mantle origin, and formed in a degrading plate boundary environment, therefore, the S-type origin is mixed with a certain degree I-type granitoid origin. At Battonya-Mezőhegyes the magma of the abyssical plutonic body was slightly compressed upwards due to an "in situ" melting in the late, kinematic phase of the Variscan Orogenesis. As a result of this, it developed a slight contact zone (Szepesházi, 1969; Szederkényi, 1984; Kovách et al., 1985).

SAMPLING AND ANALYTICAL METHODS

During our research we examined samples that are stored in the rock collection of the Department of Mineralogy, Geochemistry and Petrology, University of Szeged. The following boreholes were examined: Battonya-3, 6, 10, 36, 37, 41, 43, 44, 47, 48, 49, 63, 64, 71, 72, 75, 76; Battonya-K-4, 6, 9, 10, 11, 13, 14, 15, 16, 17, 18; Dombegyháza-DNY-1, 2; Kunágota-1, 2; Mezőhegyes-1, 2, 5, 6, 7, 8, 9, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20; Mezőhegyes-K-1; Végegyháza-2; Végegyháza-K-1 (Fig. 2B). The samples are drill-cores, and both their number and quantity are very limited. The stratigraphical columns of the most relevant Battonya High (Fig. 2A-B) boreholes, that provided the studied granitoid samples, can be seen on Fig. 3. As a part of the geological investigations in this area more than 150 modal analyses and 18 chemical analyses were performed on the studied rocks. The major element composition of samples representing the main rock types was determined with an atomic emission spectrometer (ICP-AES) at the University of Stockholm. The excitation source of the instrument is an inductively coupled plasma (ICP). 50 fixed spectral lines are installed in the spectrometer, thus their simultaneous use (polychromator) makes the multi-element analysis very fast. Besides, it is also equipped with a scanning monochromator. The instrument, named "Spectroflame Modula", was manufactured in Germany by Spectro Analytical Instruments.

PETROGRAPHY

The samples are mainly of light grey, greenish grey colour. Most of them have a holocrystalline, inequigranular texture, some samples are of equigranular texture. The macroscopic components of the studied granites are quartz, potassium feldspar, plagioclase feldspar, mica (the later can be ±biotite or ±muscovite). The usual size of the main rock forming grains falls between 1-3 mm, therefore, the studied rocks can be considered medium-granular. Subordinately, the rocks can be of bimodal composition, i.e., in a fine-grained matrix phenocrysts are placed, which probably developed due to tectonic effects. In case of some samples, based on the ordered setting of mica, features of textural orientation can be observed, too.

Primarily, the samples are solid and compact rocks, however, this state can be modified by weathering and tectonical effects. As a result of weathering the feldspars form fine dust, while the biotite is chloriticised. Carbonate and limonitic veins penetrate the rocks. As a result of tectonical wearing the texture of the rocks is broken up and gets fragmented, the rock-forming minerals are deformed.

Textural features of the studied samples

During the microscopic analyses the most important textural characteristics and the volumetric percentage were examined in terms of all the main rock forming minerals, accessory and secondary minerals. On the basis of their textures, the studied rocks can be classified in the following four groups:

a., rocks of medium-grained, inequigranular, hypidiomorphic-granular texture;

b., rocks of coarse-grained, hypidiomorphic-granular texture;

c., rocks of medium-grained, equigranular, hypidiomorphic-granular texture;

d., rocks with textural orientation.

Concerning the mineral composition and texture of the rocks, significant differences cannot be detected. On the basis of their composition, the rocks can be considered of similar character. The main rock forming minerals of the studied samples are: quartz ± orthoclase + microcline + plagioclase feldspar (albite-oligoclase) ± biotite + muscovite.

The textural features of the main mineral components are as follows:

quartz: xenomorphous, undulating absence (Fig. 4A), average grain-size is 2-3 mm. In case of several samples as a result of recrystallisation larger grains transform into subgrains (Fig. 4B). As an inclusion and secondary component it occurs in microcline and plagioclase feldspars. At the contact of microcline and plagioclase it appears in the form of myrmekite in the plagioclase (Fig. 4C).

orthoclase: hypidiomorphous, an average 1,5-3 mm size, tabular appearance. Bifold twinning is common, at some places it is perthitic.

microcline: a component of hypidiomorphous, xenomorphous, perthitic, tabular character (Fig. 4D). Its average size is 2-4 mm, however, porphyroblasts of 2-3 cm are not rare either. It contains inclusions of quartz, plagioclase feldspar, mica and zircon. More common than orthoclase, and it is present in a higher volumetric percentage.

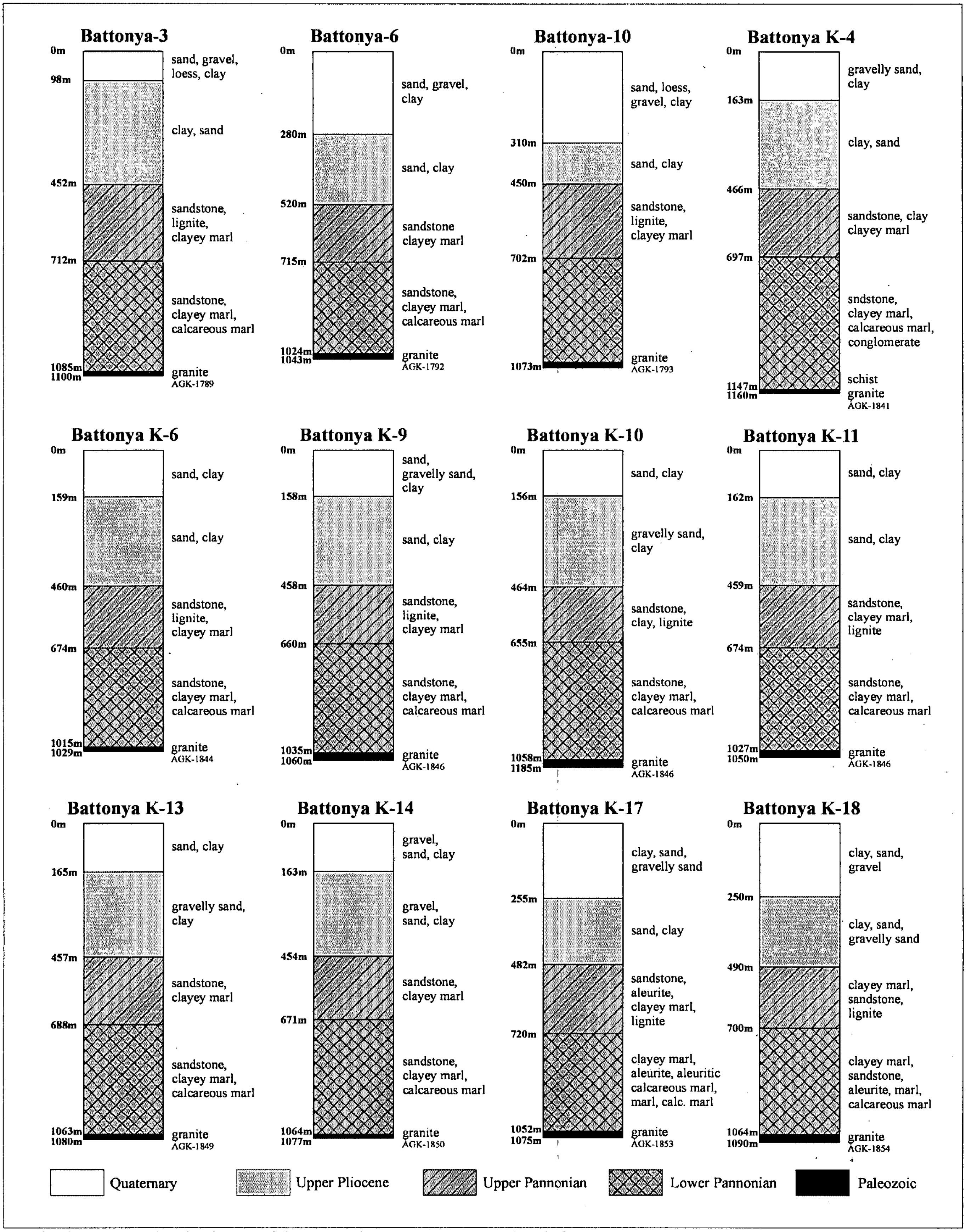


Fig. 3. The stratigraphical columns of the most relevant Battonya Unit boreholes.

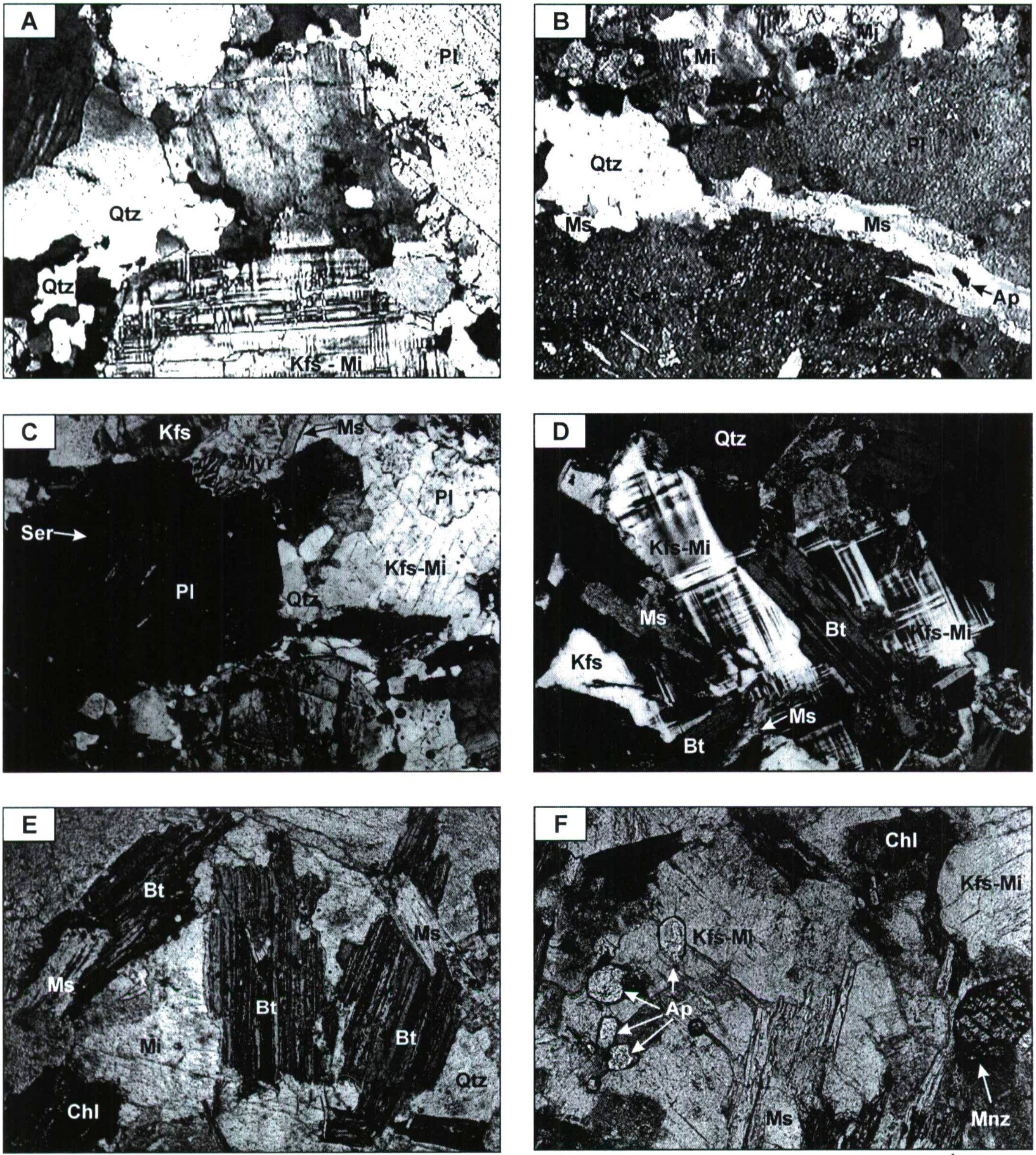


Fig. 4. Photomicrographs showing the mineral composition and texture of the studied granitoids. **(A)** sample ÁGK-1789 (Battonya-3), monzogranite, (+N, x50); **(B)** sample ÁGK-1807/1 (Battonya-36), syenogranite, (+N, x50); **(C)** sample ÁGK-1314 (Dombegyháza Dny-1), (+N, x50); **(D)** sample ÁGK-1841 (Battony K-4), syenogranite, (+N, x50); **(E)** sample ÁGK-1813 (Battonya-41), monzogranite, (1N, x50); **(F)** sample ÁGK-1848 (Battonya K-11), syenogranite, (1N, x100). Abbreviations: Ap – apatite, Bt – biotite, Chl – chlorite, Kfs – K-feldspar, Mi – microcline, Mnz – monazite, Ms – muscovite, Pl – plagioclase, Qtz – quartz, Ser – sericite.

plagioclase feldspar: hypidiomorphous, tabular, often zoned. Its average size is 1-3 mm. Often it is highly seriticised (Fig. 4B-C), less frequently carbonate and epidote grains occur in it as secondary minerals.

biotite: hypidiomorphous, an average size of 1-3 mm. Its pleochlorism is brownish yellow – brownish green (Fig. 4E). Due to the transformation, often only its chlorite pseudomorph is present (Fig. 4F). It occures in plagioclase feldspar and microcline as an inclusion. Accessory minerals are apatite and zircon. Secondary components are: chlorite rutile, leucoxene, opaque minerals, sericite, carbonate, limonite and epidote.

muscovite: hypidiomorphous grains of an average 1-3 mm size. It occurs either with biotite or alone (Fig. 4E). Some places it forms kink bands (Fig. 4B). Along the cleavages secondary carbonate precipitates.

Accessory components in the studied rocks are apatite, monacite (Fig. 4F), zircone and less frequently titanite.

The rocks mentioned above has been modified to a smaller or larger extent (chloritisation, sericitisation, or rarely saussiritisation). As a result of these transformations the following secondary components appeared: chlorite, sericite, carbonate, epidote, titanite, limonite and opaque components.

Affected by deformations, the main rock forming minerals change, as it was experienced in case of the rocks of textural group d.

On the basis of modal measurements in the Q-A-P diagram (Le Maitre, 1989), the studied rocks plot to three different fields (Fig. 5): syenogranite, monzogranite, and granodiorite

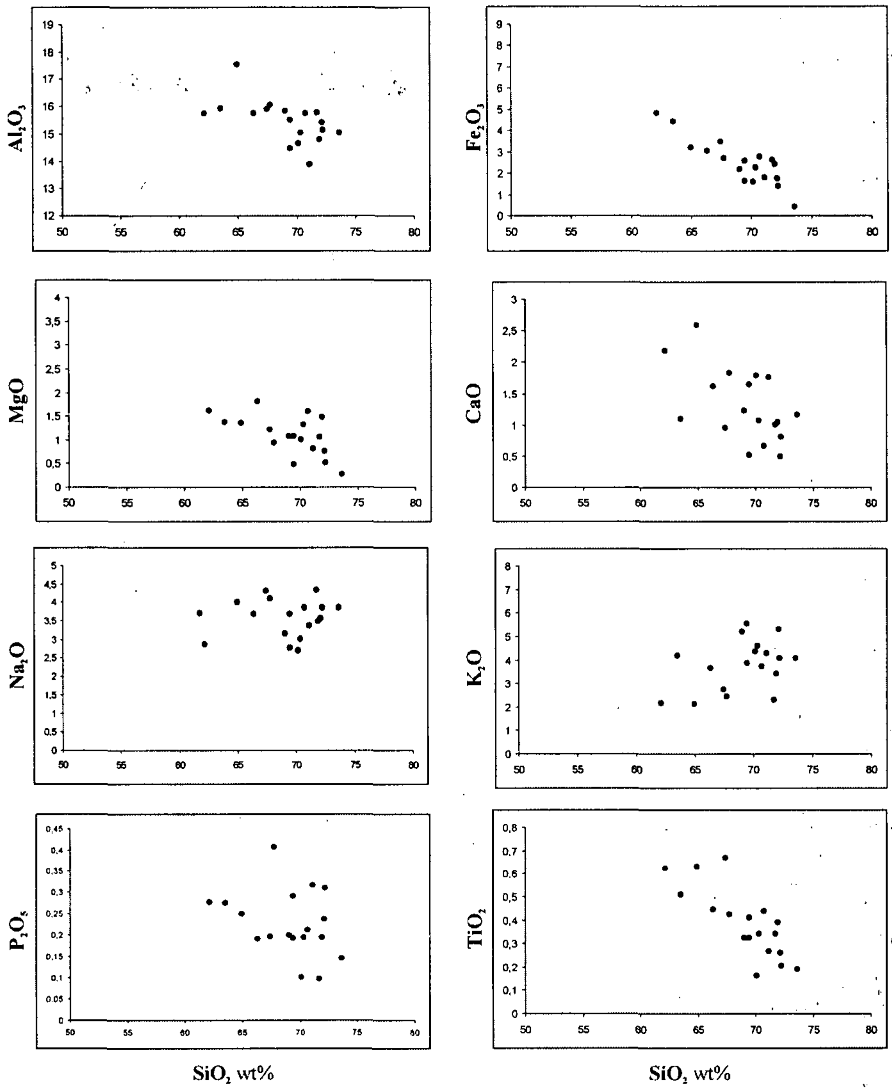


Fig. 6. Harker diagrams for major elements.

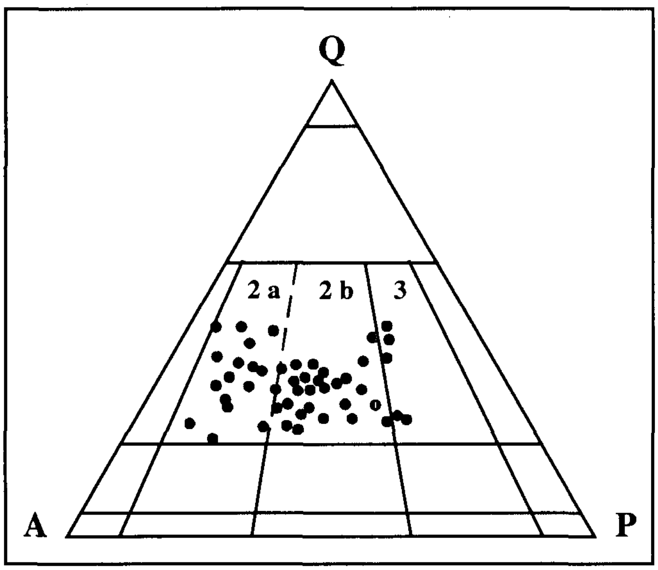


Fig. 5. Modal classification according to the IUGS (Le Maitre, 1989). 2a - syenogranite, 2b - monzogranite, 3 – granodiorite.

MAJOR ELEMENT GEOCHEMISTRY

Eighteen samples were analysed with respect to their major element composition (Table 1).

The SiO_2 content varies between 62.10 and 73.60 wt% (mean value: 69.07 wt%). The alkali content is high: K_2O is between 2.12 and 5.54 wt% (mean value: 3.76 wt%), Na_2O is between 1.68 and 4.01 wt% (mean value: 3.42 wt%). Calcium and magnesium contents are low to moderate; 0.50-2.58 wt% CaO and 0.28-1.81 wt% MgO. However, iron content is relatively high: 0.44-4.82 wt% (mean value: 2.80) $Fe_2O_3^*$ (total Fe). The $Fe_2O_3^*$/($Fe_2O_3^*$+MgO) ratio varies between 0.59 and 0.77.

The normative corundum content of the studied granitoid samples proved to be higher than 2.50 wt% in all cases, the average normative corundum content is 3.99 wt%.

Harker variation diagrams for major elements are shown in Fig. 6. Al_2O_3, $Fe_2O_3^*$, MgO, CaO, P_2O_5, and TiO_2 all decrease with increasing silica content, nevertheless, K_2O increases with increasing silica content and Na_2O content is more or less constant.

The studied rocks were classified on the basis of a total alkalis *vs.* silica diagram (Cox et al., 1979, adapted by Wilson, 1989). The samples plotted to the granite and granodiorite fields (Fig. 7).

When applying the geochemical system of De la Roche et al. (1980) the rocks proved to be syenogranites, monzogranites and granodiorites (Fig. 8).

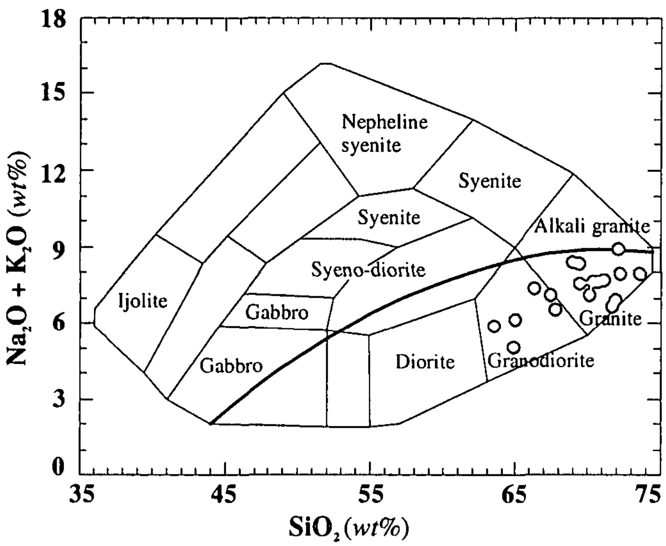


Fig. 7. The chemical classification and nomenclature of plutonic rocks using the total alkalis versus silica (TAS) diagram of Cox et al. (1979) adapted by Wilson (1989) for plutonic rocks. The curved solid line subdivides the alkali from subalkali rocks.

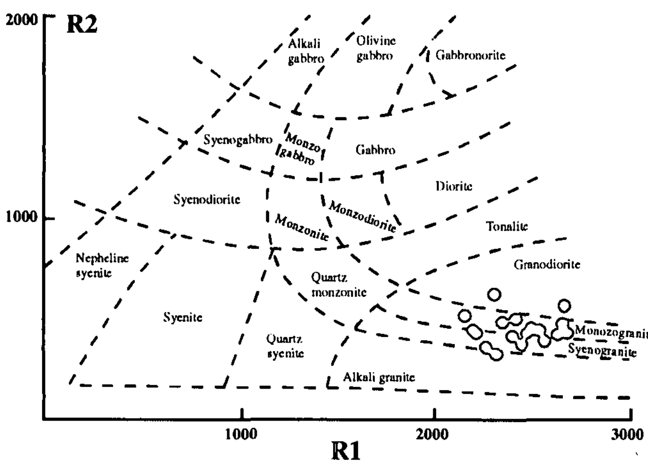


Fig. 8. Geochemical classification of plutonic rocks using parameters R1 and R2 (after De la Roche et al., 1980), calculated from milication proportions. R1 = 4Si-11(Na+K)-2(Fe+Ti); R2 = 6Ca+2Mg+Al

Based on Irvine, Baragar (1971), the rocks are subalkaline (Fig. 9), while according to Peacock's alkali-lime index (Peacock, 1931) they are calcic (Fig. 10).

The granites are peraluminous after Shand's index in the modified Maniar, Piccoli (1989) diagram (Fig. 11).

Concerning the tectonical environment, granitoid rocks can be orogenic or anorogenic. The orogenic class comprises

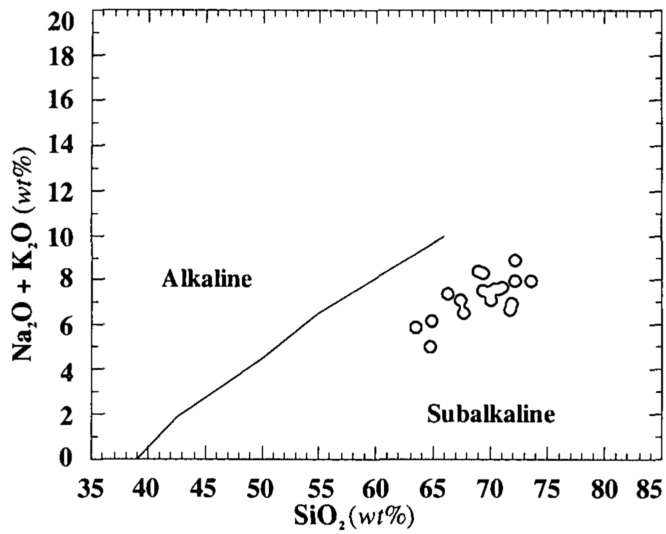


Fig. 9. SiO_2 *vs.* Na_2O+K_2O diagram according to Irvine, Baragar (1971).

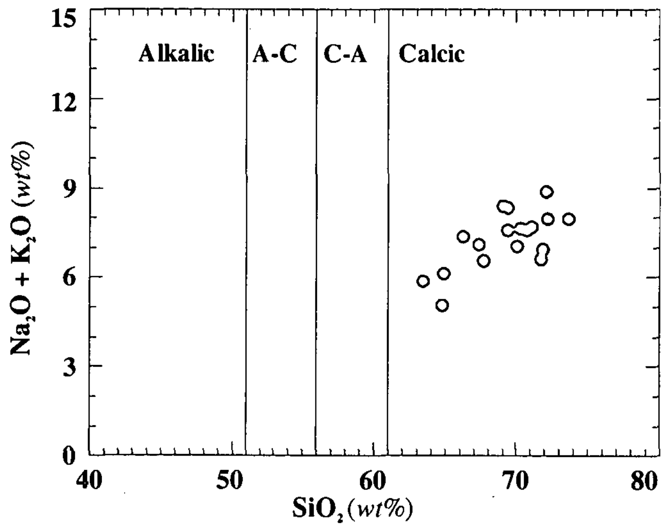


Fig. 10. Variation diagram for SiO_2 versus Na2O+K_2O (Peacock, 1931).

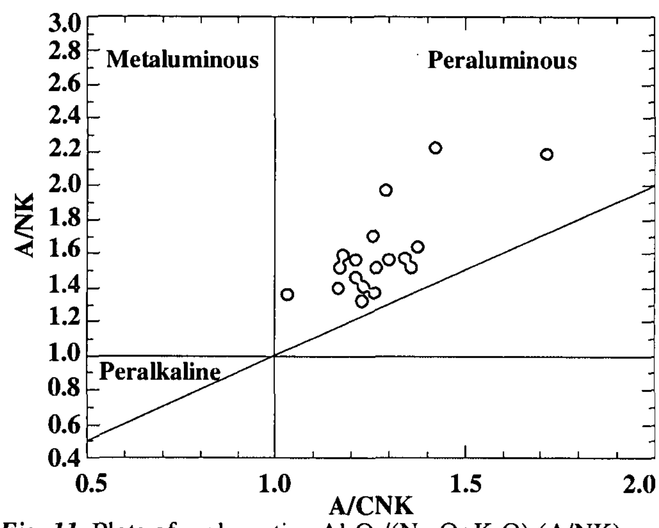


Fig. 11. Plots of molar ratios $Al_2O_3/(Na_2O+K_2O)$ (A/NK) *vs.* molar ratios $Al_2O_3/(CaO+Na_2O+K_2O)$ (A/CNK) (Maniar et al., 1989).

island arc granitoids (IAG), continental arc granitoids (CAG), continental collision granitoids (CCG), and post-orogenic granitoids (POG). Members of the anorogenic class are rift-related granitoids (RRG), continental epirogenic uplift granitoids (CEUG) and oceanic plagiogranites (OP) (Maniar et al., 1989). On the basis of the SiO_2 *vs.* K_2O system (Fig. 12A) the OP group can unambiguously be excludeded (Maniar et al., 1989). According to the SiO_2 *vs.* $FeO^t/(FeO^t+MgO)$ (Fig. 12B), and the SiO_2 *vs.* Al_2O_3 (Fig. 12C) diagarms (Maniar et al., 1989) our studied rocks are orogenic granitoids (IAG+CAG+CCG). In case of CCG the A/CNK ratio (Fig. 11) cannot be lower than 1.05, in the meantime the A/CNK ratio of the IAG+CAG group cannot be higher than 1.15. Since, in our case the A/CNK ratio, with one exception (Mezőhegyes-13-ÁGK1603; A/CNK=1.036), is always higher than 1.15 (A/CNK=1.168-1.716), the studied samples are CCG.

If we consider the R1 vs. R2 system of Batchelor, Bowden (1985) (Fig. 13), which predicts well the tectonic environment of granitoid formation, the analysed rocks can be interpreted as syn-collisional type granitoids.

Chappell, White (1974) designated granites extracted from a sedimentary protholith as S-type granites, while granites from an igneous protholith as I-type granites. White (1979) isolated also an A-type alkali granite, that occurs on continental plates. S-type granitoids are related mainly to compressional tectonic movements at the collision belt of two continental plates, and develop in the ultrametamorphous zone of the sediment-rich continental crust. The ASI $[Al_2O_3/(CaO+K_2O+Na_2O)]$ value of S-type granitoids is > 1.15, the CIPW norm yields > 1% corundum, and they are characterised by a relatively low Na/K ratio, which is a basic criterion (Zen, 1988). Usually, they are two-mica granites, mostly with monazite content. The syn-tectonic Battonya Unit granites are peraluminous, contain muscovite and biotite, and exhibit most of the features associated with S-type granites. On the basis of the major element analysis, the normative corundum content of the studied granites is higher than 1 wt% (mean value: 3,99 wt%), and the Na/K ratio is relatively low. More accurate classification is possible in the future on the basis of trace element content.

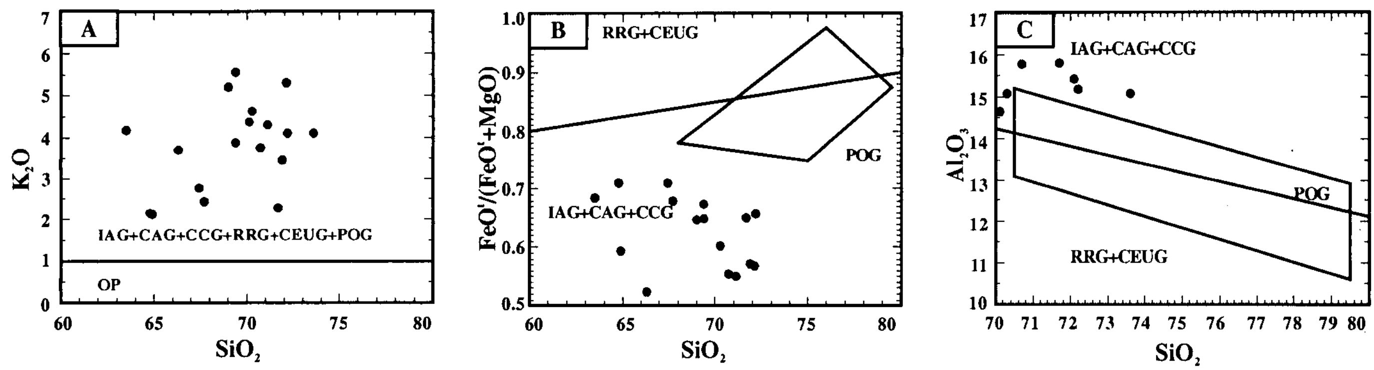


Fig. 12. A selection of diagrams after Maniar et al. (1989). **A.** SiO_2 *vs.* K_2O; **B.** SiO_2 *vs.* $FeO^t/(FeO^t + MgO)$; **C.** SiO_2 *vs.* Al_2O_3. Abbreviations: IAG = island arc granitoids, CAG = continental arc granitoids, CCG = continental collision granitoids, POG = post-orogenic granitoids, RRG = rift-related granitoids, CEUG = continental epirogenic uplift granitoids, OP = oceanic plagiogranites.

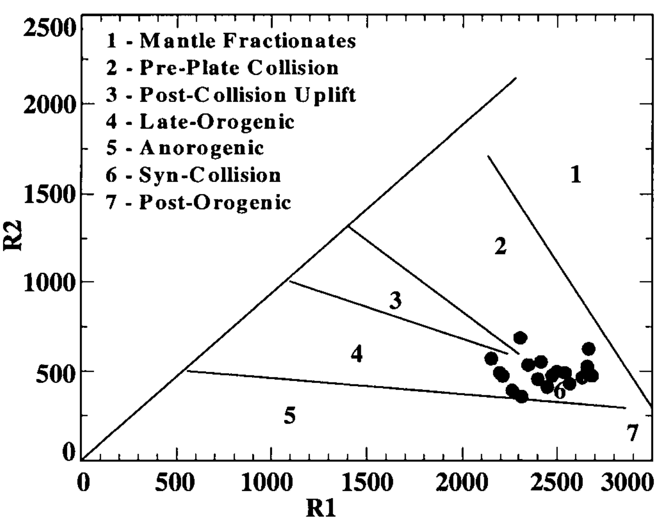


Fig. 13. Tectonical discrimination plots of Batchelor, Bowden (1985). $R_1 = 4Si - 11(Na+K) - 2(Fe+Ti)$; $R_2 = 6Ca + 2Mg + Al$.

CONCLUSIONS

(1) On the basis of their composition, the granitoid rocks of the available Battonya Unit boreholes can be considered of similar character. The main rock forming minerals of the studied samples are: quartz ± orthoclase + microcline + plagioclase feldspar (albite-oligoclase) ± biotite + muscovite. Accessory components are apatite, zircone, monacite and less frequently titanite. Their modal composition refers to that of syenogranites, monzogranites and granodiorites.

(2) On the basis of their chemical composition the studied rocks are subalkaline and calcic syenogranites, monzogranites and granodiorites with a peraluminous character.

(3) From a tectonical aspect the studied rocks are of orogenous, syn-collisional, continental collisional origin (CCG).

(4) Most of the characteristics featuring the Battonya Unit granitoids indicate that they are S-type granitoids.

Table 1. Major element data for Battonya Unit granitoids.

wt %	Battonya-48 ÁGK-1816 1174-1176 m	Battonya-63 ÁGK-1835 1029-1034 m	Battonya-72 ÁGK-1837 1136-1137 m	Battonya K-9 ÁGK-1846 1058-1060 m	Battonya K-11 ÁGK-1848 1046-1050 m	Battonya K-13 ÁGK-1849 1069-1071 m	Battonya K-14 ÁGK-1850 1075-1077 m	Battonya K-17 ÁGK-1853 1052-1075 m
SiO_2	72.1	73.6	72.2	70.3	70.7	66.3	69.4	71.9
Al_2O_3	15.41	15.07	15.16	15.05	15.77	15.76	15.53	14.8
TiO_2	0.263	0.193	0.207	0.343	0.441	0.447	0.411	0.392
$Fe_2O_3^*$	1.761	0.441	1.43	2.299	2.799	3.075	2.599	2.452
MnO	0.041	0.021	0.038	0.056	0.056	0.068	0.054	0.053
CaO	0.5	1.164	0.816	1.071	0.669	1.618	1.654	1.045
MgO	0.763	0.2805	0.517	1.321	1.615	1.814	1.081	1.493
K_2O	5.3	4.092	4.089	4.617	3.727	3.683	3.87	3.439
Na_2O	3.582	3.866	3.873	3.011	3.87	3.695	3.687	3.494
P_2O_5	0.238	0.147	0.309	0.194	0.212	0.191	0.193	0.195

Table 1 (continued)

wt %	Battonya K-18 ÁGK-1854 1079-1082 m	Mezőhegyes-13 ÁGK-1603 1184.5-1190 m	Mezőhegyes-15 ÁGK-1605 1194-1198 m	Mezőhegyes-18 ÁGK-1609 1220-1220.8 m	Mezőhegyes-19 ÁGK-1610 1180-1182.5 m	Mezőhegyes-20 ÁGK-1612 1184-1186 m	Mezőhegyes K-1 ÁGK-1613 1328-1330 m
SiO_2	69	71.1	62.1	67.4	64.9	69.4	71.7
Al_2O_3	15.84	13.88	15.76	15.92	17.57	14.49	15.79
TiO_2	0.323	0.268	0.624	0.671	0.632	0.325	0.341
$Fe_2O_3^*$	2.22	1.789	4.829	3.504	3.217	1.632	2.65
MnO	0.050	0.039	0.062	0.034	0.045	0.013	0.048
CaO	1.232	1.773	2.189	0.956	2.589	0.52	1.011
MgO	1.09	0.818	1.63	1.231	1.368	0.482	1.073
K_2O	5.2	4.285	2.167	2.769	2.126	5.54	2.291
Na_2O	3.166	3.388	2.885	4.334	4.017	2.769	4.349
P_2O_5	0.200	0.318	0.277	0.198	0.251	0.292	0.099

Table 1 (continued)

wt %	Dombegyház DNY-2 ÁGK-1315 1350-1352 m	Kunágota-1 ÁGK-1318 1797-1804 m	Kunágota-2 ÁGK-1317 1908-1911 m
SiO_2	67.7	70.1	63.5
Al_2O_3	16.06	14.65	15.93
TiO_2	0.428	0.163	0.511
$Fe_2O_3^*$	2.719	1.599	4.439
MnO	0.055	0.017	0.047
CaO	1.84	1.79	1.097
MgO	0.941	1.019	1.378
K_2O	2.439	4.366	4.175
Na_2O	4.115	2.707	1.682
P_2O_5	0.409	0.102	0.276

(*given as total iron content)

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